COMPETITION, MONOPOLY MAINTENANCE,

AND CONSUMER SWITCHING COSTS

by

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ABSTRACT

Significant recent attention has been paid to why a durable goods producer with little or no market power would monopolize the maintenance market for its own product. This paper provides a new explanation for this practice that is based on consumer switching costs and the choice of consumers between maintaining and replacing used units. In our explanation, if a firm does not monopolize the maintenance market for its own product, then consumers sometimes maintain used units when it would be efficient for the units to be replaced. In turn, the return to monopolizing the maintenance market is that the practice allows firms to avoid this inefficiency. An interesting aspect of our analysis is that, in contrast to most previous explanations for why a durable goods producer would monopolize the maintenance market for its own product, in our explanation the practice increases rather than decreases both social welfare and consumer welfare.

I. INTRODUCTION

In a series of recent court cases there have been allegations that a variety of firms such as Kodak, Data General, Unisys, and Xerox have monopolized the maintenance markets for their own products. A typical allegation is that the durable goods producer refuses to sell spare parts to alternative maintenance suppliers with the result that consumers of the firm's products have no option but to purchase maintenance from the original durable goods producer. In this paper we explore a new explanation for this practice that is based on consumer switching costs and the choice of consumers between maintaining and replacing used units. In particular, we show that the practice can be used by firms to avoid an inefficiency concerning consumer maintenance decisions, where, in contrast to most previous analyses of the issue, in our analysis the practice increases both social welfare and consumer welfare.

Much of the recent attention to this issue stems from the 1992 Supreme Court decision in the case *Eastman Kodak Company v. Image Technical Services, Inc., et al*. Consistent with the above discussion, in that case Kodak was alleged to have monopolized the maintenance market for its copiers and micrographic equipment by refusing to sell spare parts to alternative maintenance suppliers. The Supreme Court ruled that, even if Kodak had no market power in the market for new equipment, a potentially relevant antitrust concern was Kodak's behavior in the maintenance market for its own products. The Court thus concluded that Kodak's alleged behavior of monopolizing the maintenance market for its own products by refusing to sell spare parts to alternative maintenance suppliers was at least a potential antitrust violation.

This paper investigates from a theoretical standpoint the Supreme Court's ruling that, even when a firm has little or no market power in the market for new units, a firm's behavior in the maintenance market for its own products can constitute an antitrust violation. We consider a two-period model characterized by perfect competition in the market for new units in which new units sold in the first period become used units in the second period that require maintenance, where an important aspect of the model is that the required level of maintenance for a used unit is stochastic. Our model incorporates two of the main features of the Kodak case and a number

of the other cases in which monopolizing the maintenance market has been alleged. First, each durable goods producer has the option of monopolizing the maintenance market for its own product. By this we mean that in the second period each durable goods producer has the option of becoming the sole supplier of maintenance for the used units it sold as new in the first period. Second, the market for new units is characterized by consumer switching costs.[1] This is important because, due to switching costs, a firm that sells new units in the first period has some market power in the new-unit market in the second period.[2]

Analysis of this model yields two important findings. First, if the maintenance market is competitive and durable goods producers cannot commit in the first period to a second-period price for new units, then both social welfare and consumer welfare are below the levels achieved when commitment is possible. The logic for this result is as follows. If a firm could commit to a second-period price for new units, then the firm would commit to a second-period price equal to the marginal cost of production because this results in consumers making efficient choices concerning whether to maintain or replace used units. However, if firms lack the ability to commit, then due to switching costs each firm maximizes its second-period profits by charging a second-period price above marginal cost. The result is that, since maintenance is priced

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[1] There is an extensive literature that investigates models characterized by consumer switching costs. Papers in this literature include Klemperer (1987,1989) and Farrell and Shapiro (1988,1989). See also the earlier work of Williamson (1975,1985). Klemperer (1995) surveys the literature.

[2] The allegations against Kodak in the 1992 case contained a number of detailed accounts of switching costs faced by consumers of Kodak's products. For example,

> "The system at CSC includes a combination of micrographics machines, and of computer hardware and software tailored specifically to CSC's needs. Trading its entire equipment for an "interbrand" competitor of Kodak, due to supra-competitive prices, it would be financially unfeasible for CSC. The special software would have to to retailored at a cost of several hundred thousand dollars. Data would have to be reformatted and operators would have to be retrained, again, at a cost of hundreds of thousands of dollars..."
> (Plaintiff's Memorandum in *Eastman Kodak Co. v. Image Technical Services, Inc., et al.* (1992), pp. 19-20)

The allegations also state that similar systems to the one described above were found in a variety of places such as "Blue Cross/Blue Shield, insurance companies, banks, and other large financial institutions in many states." (Plaintiff's Memorandum in *Eastman Kodak Co. v. Image Technical Services, Inc., et al.* (1992), p. 19)

competitively while the price for new units is above the competitive price, consumers in the second period sometimes maintain used units when it would be efficient for the units to be replaced.

Our second finding is that, if each durable goods producer has the ability to monopolize the maintenance market for its own product, then each firm monopolizes the maintenance market and avoids the inefficiency described above, i.e., both social welfare and consumer welfare increase. To see the logic for this result consider a durable goods producer that sells a strictly positive number of new units in the first period and monopolizes the maintenance market for its own product at the beginning of the second period. By optimally setting the second-period price for new units and the price schedule associated with different levels of maintenance, the firm extracts all the second-period surplus from the consumers who purchased new units from the firm in the first period (there is second-period surplus both because of the switching cost and because a used unit may require little maintenance). In turn, since the firm extracts all the second-period surplus, the firm has an incentive to behave in a manner that maximizes that surplus. The result is that both social welfare and consumer welfare increase because in the second period consumers efficiently choose whether to maintain or replace their used units.

Most previous researchers who have modeled a competitive durable goods producer that monopolizes the maintenance market for its own product argue that the behavior reduces social welfare because it causes a standard deadweight loss due to monopoly pricing in the maintenance market (see the discussion in Section IV and earlier discussions in Shapiro (1995) and Chen, Ross, and Stanbury (1998)). Our analysis shows that there is another possibility for what happens when a competitive durable goods producer monopolizes the maintenance market for its own product. That is, the behavior can serve to eliminate a social welfare distortion present in the maintenance market due to consumer switching costs. From a public policy perspective this is a crucial difference because, if the behavior serves to eliminate a social welfare distortion present in the maintenance market, then the behavior increases rather than decreases social welfare and should be allowed.

This paper is related to Carlton and Waldman (2000). That paper makes the general point that a competitive maintenance market is not always an efficient maintenance market, and that when this is the case the monopolization of an aftermarket can serve to increase rather than decrease social welfare. Further, one of the settings they analyze to demonstrate this point is the same basic setting analyzed here, i.e., a competitive durable goods industry in which used units require maintenance and there are consumer switching costs. However, our paper analyzes this setting in much more detail than do Carlton and Waldman (2000). For example, we show why a durable goods producer would prefer to monopolize the maintenance market for its own product rather than sign a long-term contract that specifies the future price for replacement units, and why a firm would monopolize the maintenance market for its own product by refusing to sell spare parts to alternative maintenance suppliers rather than simply increase the price for spare parts. Also, we show that results generalize to the case of heterogeneous consumers while Carlton and Waldman focus solely on the case of identical consumers, and that results generalize to the case of endogenous durability choice while in Carlton and Waldman's analysis durability is given exogenously.

The outline for the paper is as follows. Section II constructs a model characterized by perfect competition in the market for new units and consumer switching costs. Here we identify an inefficiency that arises when durable goods producers in the first period cannot commit to the second-period price for new units, and show that a firm can avoid the inefficiency by monopolizing the maintenance market for its own product. Section III discusses two extensions of our model. The first explains why a firm would monopolize the maintenance market for its own product rather than sign a long-term contract that specifies the future price for replacement units. The second explains why a firm would monopolize the maintenance market for its own product by refusing to sell spare parts to alternative maintenance suppliers rather than simply increase the price for spare parts. Section IV discusses alternative explanations for why a firm would monopolize the maintenance market for its own product and the antitrust implications of our analysis. Section V presents concluding remarks.

II. MONOPOLY MAINTENANCE AND CONSUMER SWITCHING COSTS

Our analysis builds on an insight found in earlier papers such as Schmalensee (1974), Su (1975), and Rust (1986). Those papers consider durable goods monopoly settings in which consumers must decide between replacing and maintaining their used units, where the maintenance market is competitive. They show that, because the durable goods monopolist charges a price for a new unit of output that is above the firm's marginal cost of production while maintenance is priced competitively, consumers sometimes maintain used units when it would be efficient for the consumers to purchase new units.

In this section we construct a model in which the market for new units is perfectly competitive, but consumer switching costs and the lack of ability to commit cause each firm to charge a price for replacement units that is above the marginal cost of production. The result is that, if firms sell new units and do not monopolize the maintenance market, then, as in the analyses of Schmalensee, Su, and Rust, consumers maintain used units inefficiently often. We then show that a competitive durable goods producer that monopolizes the maintenance market for its own product avoids this inefficiency. In the next section we explore the robustness of our main results by considering two extensions.

A) The Model

We consider a two-period setting in which there are two perfectly competitive industries, where one produces a durable good while the other supplies maintenance for this good. Each durable goods producer has a constant marginal cost of production equal to c and no fixed costs of production, where a unit lasts two periods. A new unit of output requires no maintenance while a used unit requires maintenance, where new and used units are perfect substitutes if the used unit receives the required level of maintenance. We also assume that a used unit that does not receive the required level of maintenance cannot be used for consumption and has a scrap value equal to z, $z<c$.

The level of maintenance required by a used unit of output, denoted m, is a stochastic variable. In particular, the level of maintenance required by a used durable unit produced by any firm j is the realization of a random draw from the probability density function f(.), where f(m)>0 for all m∈(0,M] and f(m)=0 for all m outside this interval.[3] We also assume that the realization of m for any specific used unit is privately observed by the individual who consumed the unit in the first period, where m_i denotes the level of maintenance required by the used unit consumed by individual i in the first period.[4] This specification allows us to capture the idea discussed above that when replacement units are priced above marginal cost an inefficiency results in which too many used units are maintained rather than scrapped and replaced.

Maintenance for a durable unit produced by firm j can be supplied either by a firm in the perfectly competitive maintenance industry or by firm j itself, where each type of firm has no fixed costs of supplying maintenance while the variable costs of supplying maintenance of level m equal m. Note, since the maintenance industry is perfectly competitive, firms in this industry are willing to sell maintenance of level m at a price equal to m. We also assume 0<c-z<M. This assumption tells us that it is efficient for some used units to be maintained and for other used units to be scrapped and replaced. We allow for two possibilities concerning the maintenance market. We first assume that each durable goods producer cannot stop consumers of the firm's product from purchasing maintenance from firms in the competitive maintenance industry. We then assume that each durable goods producer can stop consumers of its product from purchasing

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[3] We also assume f(.) is such that when the maintenance market is competitive and firms cannot commit in the first period to a second-period price for new units, there is a unique second-period price for new units that maximizes second-period profits for a firm that sells a strictly positive number of new units in the first period. This condition will be satisfied, for example, if m is uniformly distributed over the interval (0,M]. Note, this assumption is not at all crucial but serves to simplify both the statements of the propositions and the proofs.

[4] One way to justify m_i being privately observed by consumer i is by assuming that m_i is a function of the number and severity of the machine's random malfunctions in the first period, and the only individual who has direct knowledge of this is consumer i. In this interpretation the stochastic variable is the number and severity of first-period malfunctions. Note, the reason m_i being privately observed is important is that it means that a durable goods producer cannot make the new-unit price it offers a consumer in the second period contingent on the consumer's realization for m_i, and this, in turn, limits a durable goods producer's ability to price discriminate in the second period if it does not monopolize the maintenance market for its own product.

maintenance from the competitive maintenance sellers and in this way monopolize the maintenance market for its own product.

A related assumption is that each durable goods producer's decision concerning whether or not to monopolize the maintenance market for its own product occurs at the beginning of the second period rather than at the beginning of the first. As will be discussed later, this assumption is not at all crucial for the results. Rather, we make this assumption to better capture the circumstances in the case *Eastman Kodak Co. v. Image Technical Services, Inc., et al*. The allegation against Kodak in that case was that starting in 1985 the firm monopolized the maintenance markets for its own products by refusing to sell spare parts to alternative maintenance suppliers, where prior to 1985 Kodak did sell spare parts to alternative maintenance suppliers. We believe we more accurately capture this aspect of the case by assuming that each durable goods producer decides whether to monopolize the maintenance market for its own product at the beginning of the second period rather than at the beginning of the first.[5]

On the demand side, we assume a continuum of nonatomic consumers whose total mass we normalize to one. We further assume that consumers are heterogeneous in terms of their basic valuations for the durable product and that there are consumer switching costs.[6] The specification for consumer utility in the first period is simple. In the first period each consumer i receives a gross benefit equal to v_i from consuming a new durable unit produced by any of the durable goods producers. Further, the distribution of v_is in the population is described by a density function g(.), where g(v)>0 for all $v \in [v_L, v_H]$, g(v)=0 for all v outside this interval, and $v_L > c$. The restriction $v_L > c$ simplifies the analysis because it rules out the possibility of a consumer purchasing a new unit in the first period and then deciding not to either maintain the

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[5] For a discussion of Kodak's monopolization of the maintenance markets for its own products see Plaintiff's Memorandum in *Eastman Kodak Co. v. Image Technical Services, Inc., et al.* (1992), pp. 2-5, 12-15, and 23-31.

[6] As far as we are aware, the only other paper that considers consumer switching costs in a setting characterized by perfect competition in the market for new units is Taylor (1999). That paper, however, does not consider durable products or maintenance.

unit or replace the unit in the second. Note that in the analysis that follows it does not matter whether each individual i's value for v_i is privately known by individual i or publicly observable.

The specification for consumer utility in the second period is more complicated because it captures the switching costs. Let Δ denote the size of the switching costs and let firm j_i be the producer of the durable unit that was consumed by individual i in the first period. We assume that in the second period each consumer i receives a gross benefit equal to $v_i+\Delta$, $\Delta>0$, from consuming either a new durable unit produced by firm j_i or a used durable unit produced by j_i that receives the required level of maintenance. On the other hand, in the second period each consumer i receives a gross benefit equal to v_i from consuming a new durable unit produced by a firm other than j_i. If consumer i did not consume a new unit in the first period, then the consumer receives a gross benefit equal to v_i from consuming a new durable unit produced by any manufacturer. It is also assumed that all firms and all consumers are risk neutral and have a discount factor β, $0<\beta<1$.

As discussed in Klemperer (1995), there are a number of factors that can lead to the type of consumer switching costs contained in the above specification. One possibility that nicely fits our specification is that there is a cost associated with learning how to operate any particular producer's product. That is, each product is somewhat idiosyncratic concerning the specifics of its operation, and as a result a consumer bears a learning cost in the first period he or she uses a particular producer's product. The result is that a consumer in the first period will bear this cost independent of which product he or she consumes, but in the second period the consumer can avoid the cost by consuming a unit produced by the same firm that produced the unit he or she consumed in the first period.

The timing of events is as follows. The first period consists of two stages. First, each durable goods producer chooses the price at which it will sell a new unit of output.[7] Second, each consumer makes his or her purchase decisions. The second period consists of three stages.

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[7] As indicated, we assume that firms sell as opposed to lease new units of output. See footnote 11 for a discussion of what would happen if we were to allow leasing.

First, when monopolizing the maintenance market is an option, each durable goods producer decides whether to allow competition in that market or monopolize the maintenance market for its own product. Second, each durable goods producer chooses the price at which it will sell a new unit of output.[8] At the same time, each durable goods producer that has decided to monopolize the maintenance market for its own product chooses a price schedule that specifies a price for each level of maintenance in the interval (0,M]. Third, each consumer makes his or her purchase decisions. Note that we could introduce a fourth stage in which there is trade between consumers on a secondhand market, but we do not since the introduction of such a secondhand market would not at all affect the results. Our analysis focuses on Subgame Perfect Nash Equilibria.

B) Analysis

The outline for this subsection is as follows. First, we discuss the results of a benchmark analysis in which each durable goods producer can commit in the first period to the price it will charge in the second period for a new unit of output. Second, we show that an inefficiency arises when firms cannot commit in the first period to a second-period price for new units. Third, we show that monopolizing the maintenance market allows firms to avoid this inefficiency with the result that both social welfare and consumer welfare increase.

Suppose the maintenance market is competitive and each producer can commit in the first period to the price it will charge in the second period for a new unit of output. Let $P_{jt}*$ denote the price that producer j charges for a new unit of output in period t, and EU_i* denote the present discounted value of the expected net benefits received by consumer i. This case works very simply. Each producer j chooses $P_{j1}*=P_{j2}*=c$, every consumer purchases a new unit in the first

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[8] For the analysis of the second-period pricing game we assume there is free entry into the market for new durable units in the second period as well as the first. An alternative assumption that would serve the same role is that in the second period each durable goods producer can price discriminate between consumers who previously consumed the firm's product and other consumers. Fudenberg and Tirole (1998) call the latter assumption the case of identified consumers.

period, a consumer who purchases a new unit in the second period purchases it from the same producer he or she purchased from in the first, and the result is $EU_i^* = (v_i - c) + \beta[v_i + \Delta - \int_0^{c-z} mf(m)dm - \int_{c-z}^M (c-z)f(m)dm]$ for all i. The expression for EU_i^* captures that when the realization of m is above c-z a consumer will scrap and replace the used unit and receive a net benefit of $v_i + \Delta - (c-z)$ in the second period, while a realization of m below c-z means a consumer will maintain the used unit and receive a net benefit of $v_i + \Delta - m$ in the second period.

The logic behind the above equilibrium is as follows. Because it is a competitive market, in the first period each durable goods producer will market its product in the fashion that minimizes the inefficiency associated with consuming the product. In turn, this means that each firm commits to a second-period price for new units equal to c. The reason is that this causes each first-period purchaser of the firm's product to make an efficient choice in the second period concerning whether to maintain the unit or scrap and replace the unit, i.e., the consumer chooses to maintain when m<c-z and chooses to scrap and replace when m>c-z. In turn, given that the price for new units in the second period is c, the zero-profit condition associated with perfect competition yields that the first-period price also equals c.

We now turn our attention to what happens when the maintenance market is competitive and each durable goods producer is not able to commit in the first period to the price it will charge for a new unit of output in the second period. Below P_{jt}^C denotes the price that producer j charges for a new unit of output in period t in this case and EU_i^C denotes the present discounted value of the expected net benefits received by consumer i in this case.[9]

Proposition 1: Suppose the maintenance market is competitive. If each durable goods producer cannot commit in the first period to a second-period price for new units, then there is a unique equilibrium characterized by i)-iii).

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[9] Throughout the analysis we assume that a consumer who receives the same second-period net benefit from maintaining a used unit as from scrapping and replacing the unit prefers to maintain it. This assumption is not at all crucial but serves to simplify both the statements of the propositions and the proofs.

i) $P_{j1}^C < P_{j1}* = c$ and $P_{j2}^C > P_{j2}* = c$ for every firm j that sells a strictly positive number of new

   units in the first period. Let P' denote the second-period price for a new unit chosen by

   each such firm j.

ii) Each consumer i purchases a new unit in period 1 and maintains that unit in period 2

   if $m_i \leq P'-z$, but scraps and replaces the unit with a new unit produced by firm j_i if

   $m_i > P'-z$.

iii) $EU_i^C < EU_i*$ for all i.

   Proposition 1 tells us that an inefficiency arises when firms cannot commit in the first

period to a second-period price for new units. The logic here is as follows. Think back to the

commitment case. In that case each durable goods producer committed in the first period to a

second-period price for new units equal to c. The result was that in the second period consumers

made efficient choices concerning whether to maintain or scrap and replace their used units.

Now consider what happens in the absence of commitment. In that case each firm will choose a

price for new units in the second period that is strictly above c. The reason is that setting the

second-period price for new units equal to c results in second-period profits equal to zero, but

because of the switching cost each firm can earn positive second-period profits by choosing a

second-period price above c. The result is that consumers no longer make efficient choices

concerning whether to maintain or scrap and replace their used units. Rather, because the price

for a new unit in the second period is above the firm's marginal cost of production, more

consumers maintain their used units than is efficient.

   The next step of the analysis is to consider actions that a firm might take in order to avoid

the inefficiency identified above. In particular, we explore the extent to which a competitive

durable goods producer can avoid this inefficiency by monopolizing the maintenance market for

its own product. Below P_{jt}^M denotes the price that producer j charges for a new unit of output in

period t in this case and EU_i^M denotes the present discount value of the expected net benefits

received by consumer i in this case. Also, $p_j(m)$ denotes the price that durable goods producer j

charges for maintenance of level m in the second period when it monopolizes the maintenance market for its own product.

Proposition 2: Suppose each durable good producer cannot commit in the first period to a second-period price for new units but that each durable goods producer has the option of monopolizing the maintenance market for its own product at the beginning of the second period. Then every equilibrium is characterized by i)-iv), where in each equilibrium every durable goods producer that sells a strictly positive number of new units in the first period monopolizes the maintenance market for its own product in the second period.[10]

    i) $P_{j1}^M < P_{j1}^* = c$ and $P_{j2}^M = c + \Delta > P_{j2}^* = c$ for every firm j that sells a strictly positive number

of

      new units in the first period.

    ii) $p_j(m) = c + \Delta - z$ for all $m < c - z$, $p_j(m) > c + \Delta - z$ for all $m > c - z$, and $p_j(m) \geq c + \Delta - z$ for $m = c - z$ for

        every firm j that sells a strictly positive number of new units in the first period.

    iii) Each consumer i purchases a new unit in period 1 and maintains that unit in period 2

        if $m_i < c - z$, scraps and replaces the unit with a new unit produced by firm j_i if $m_i > c - z$,

        and either maintains the unit in period 2 or scraps and replaces the unit with a new

        unit produced by firm j_i if $m_i = c - z$.

    iv) $EU_i^M = EU_i^*$ for all i.

Proposition 2 demonstrates that a durable goods producer can avoid the inefficiency identified above by monopolizing the maintenance market for its own product. The logic here is as follows. As just discussed, when the maintenance market is competitive and commitment is not possible, consumers make inefficient maintenance decisions and there is a corresponding reduction in both social welfare and consumer welfare. Now suppose that a durable goods

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[10] There are multiple equilibria because, as described in condition ii), $p_j(m)$ is not uniquely determined.

producer chooses to monopolize the maintenance market for its own product. By optimally

setting the second-period price for a new unit and the price schedule for maintenance, in the

second period the firm is able to extract all the surplus from consumers who purchased new units

from the firm in the first period (there is surplus to be captured because of the presence of the

switching cost and because some used units require a level of maintenance less than c-z). In

turn, since the firm is able to extract all the surplus, the firm has an incentive to induce

consumers to make efficient maintenance decisions. The result is that consumers make efficient

maintenance choices and social welfare and consumer welfare are the same as in the

commitment case.[11]

One interesting question concerning the above analysis relates to the timing of when a

durable goods producer decides whether to monopolize the maintenance market for its own

product. As discussed earlier, in order to better capture the circumstances of the Kodak case, in

the above analysis we assumed that each firm chooses whether to monopolize the maintenance

market for its own product at the beginning of the second period rather than at the beginning of

the first. An obvious question to ask is, to what extent would the results change if we instead

assumed that this choice was made at the beginning of the first period? The answer is that this

change in the assumptions would have no effect on the results. The reason is that in the above

analysis consumers at the beginning of the first period correctly anticipate that each firm will

monopolize the maintenance market for its own product at the beginning of the second period.

In turn, since consumers correctly anticipate this behavior at the beginning of the first period,

nothing would be changed if each firm announced at the beginning of the first period rather than

at the beginning of the second that it will monopolize the maintenance market for its own

product.[12]

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[11] We have assumed that each durable goods producer sells rather than leases its output. A durable goods producer could also avoid the inefficient consumer maintenance decisions by leasing its output and monopolizing the maintenance market for its own product. If a firm leased but did not monopolize the maintenance market, then the inefficient consumer maintenance decisions would not be avoided and both social welfare and consumer welfare would fall as a result.

As a final point, a related question regarding the above analysis concerns the allegation that Kodak's consumers were surprised by the firm's decision to monopolize the maintenance market (see Section IV for a related discussion). As just discussed, in our analysis each durable goods producer makes the decision of whether to monopolize the maintenance market at the beginning of the second period. But since consumers know about this possibility when they make their initial purchase decisions, in the second period each consumer i is not surprised when firm j_i decides to monopolize the maintenance market for its own product.

The interesting question is, how would the results change if consumers were not so foresighted? That is, suppose that, rather than correctly anticipating what will happen in the second period, consumers anticipate that in the second period the maintenance market will be competitive. The answer is that no aspect of our analysis is affected by this change. The reason is that the price for a new unit in the first period does not depend on whether consumers correctly anticipate what will happen in the second period, but rather is determined by competition among firms in the first period causing each firm to offer a price consistent with zero profits.

In summary, this section has demonstrated two important results. First, given consumer switching costs and a competitive maintenance market, if firms cannot commit in the first period to a second-period price for new units then an inefficiency arises that lowers both social welfare and consumer welfare. The logic is that, because of switching costs, firms charge a price above marginal cost for replacement units with the result that consumers sometimes maintain used units when it would be efficient for the units to be replaced. Second, when a firm monopolizes the maintenance market for its own product it avoids the inefficiency with the result that both social welfare and consumer welfare increase. The logic here is that monopolizing the maintenance

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[12] This discussion raises the question, why didn't Kodak monopolize the maintenance market right from the start, or, in our terminology, at the beginning of period 1? One potential explanation for this concerns the possibility that the alternative maintenance suppliers had a small cost advantage in providing maintenance for at least some consumers. To be specific, suppose we changed our model and assumed that new durable units require some small amount of maintenance and that the competitive maintenance suppliers have a small cost advantage in supplying maintenance to at least some consumers. Analysis of this formulation yields that each durable goods producer allows competition in the maintenance market in the first period in order to take advantage of the superior efficiency of the alternative maintenance suppliers, but monopolizes the maintenance market in the second period with the result that second-period maintenance decisions are efficient.

market allows a firm to capture all the surplus at the date that consumers are deciding whether to maintain or replace used units. Thus, when a firm monopolizes the maintenance market it has an incentive to price in such a way that consumers make efficient maintenance decisions.

III. EXTENSIONS

In this section we discuss two extensions of the model analyzed in the previous section. The first extension addresses why a firm would monopolize the maintenance market for its own product rather than sign a long-term contract that specifies the future price for replacement units. The second extension explains why a firm would monopolize the maintenance market for its own product by refusing to sell spare parts to alternative maintenance suppliers rather than simply raise the price for spare parts.[13]

A) Why Not Long-Term Contracts?

In the analysis of Section II a durable goods producer could ensure efficient maintenance decisions in either of two ways. It could ensure efficient decisions by either monopolizing the maintenance market for its own product or by signing a long-term contract with consumers in the first period that specifies the second-period price for new units. But this raises the question, since a long-term contract of this sort would not be difficult to write, why would a firm monopolize the maintenance market for its own product rather than sign such a long-term contract? In this subsection we discuss a variant of the model considered above that addresses this question.

In this extension everything is the same as in the model of Section II except that a firm in each period must choose the durability of its output, where an increase in the durability built into new units both increases the marginal cost of production and reduces the expected level of

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[13] A detailed description and analysis of each extension is available from the authors upon request.

maintenance required by the units when they become used.[14] We also assume that a firm's choice of durability in each period is neither publicly observable nor verifiable. The fact that durability is neither publicly observable nor verifiable introduces the possibility of a standard moral-hazard problem in which firms underinvest in first-period durability because the first-period price does not reflect the first-period durability choice. Note, since this is a two-period model, the first-best durability level in the second period is the minimum level and thus there is no moral-hazard problem that would cause the firms to choose a durability level different than the first-best one in the second period.

Analysis of this model yields that each firm monopolizes the maintenance market for its own product rather than sign a long-term contract that specifies the second-period price for replacement units. To understand this result, first consider why a long-term contract that specifies the second-period price for replacement units resulted in a first-best outcome in the model of Section II. In that analysis the only behavior that needed to be controlled to achieve a first-best outcome was each consumer's second-period choice concerning whether to maintain or scrap and replace his or her used unit. In turn, a firm could provide its consumers with an incentive to make efficient maintenance decisions by committing to a second-period price for replacement units equal to the marginal cost of production.

Now consider what happens given the model being considered here when a firm signs a long-term contract that specifies the second-period price for replacement units. There are now two behaviors that need to be controlled through the contract to achieve a first-best outcome. The first is that, as before, each consumer needs to make an efficient second-period choice concerning whether to maintain or scrap and replace his or her used unit, while the second is that the firm needs to make an efficient first-period choice concerning the durability of its output. Analysis of this case yields that a firm that simply commits to a second-period price for

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[14] In addition to the papers of Schmalensee (1974), Su (1975) and Rust (1986) that were mentioned at the beginning of Section II, previous papers concerning durability choice include Swan (1970,1971), Bulow (1986), Waldman (1996), and Hendel and Lizzeri (1999).

replacement units cannot induce both behaviors to be chosen efficiently. To see this, suppose a firm committed to a second-period price for new units equal to the marginal cost of production that corresponds to the first-best level of durability in the second period (this is the second-period price needed for the replacement versus maintenancen decisions to be efficient). Given this commitment, the firm would not have an incentive to choose the first-best level of durability in the first period. The reason is that for any first-period durability choice the firm would earn second-period profits equal to zero by committing to this price for replacement units in the second period, but, given that a firm's first-period durability choice is unobservable, this means the firm has an incentive to choose the minimum durability level rather than the first-best durability level in the first period.

The final step of the argument is to consider what happens when a firm chooses to monopolize the maintenance market for its own product rather than commit to a second-period price for replacement units. The result is that the firm makes the efficient choice concerning first-period durability and consumers make efficient maintenance decisions, where the logic for this result is the same as the logic for why monopolizing the maintenance market resulted in first-best behavior in Section II. By monopolizing the maintenance market a firm in the second period is able to extract all the surplus from consumers who purchased new units from the firm in the first period. In turn, since the firm is able to extract all the surplus, the firm has an incentive for decisions to be efficient. The result is that consumers make efficient maintenance choices and the firm chooses the first-best level of durability in the first period.

B) <u>Why Not Increase the Price for Spare Parts?</u>

One interesting aspect of the allegations against Kodak and the other firms that have monopolized the maintenance markets for their own products concerns the manner with which that monopolization is typically achieved. As mentioned in the Introduction, a typical allegation is that the durable goods producer monopolizes the maintenance market for its own product by refusing to sell spare parts to alternative maintenance suppliers. But as pointed out earlier by

Chen, Ross, and Stanbury (1998), this raises the question, why doesn't the firm simply increase the price for spare parts rather than refuse to sell spare parts and monopolize the maintenance market? Here we discuss a variant of the model considered in Section II that addresses this question.

In this extension everything is the same as in the model of Section II except that maintenance consists of both service and replacement parts, where a used unit of output requires one unit of service and a stochastic number of replacement parts. As in the model of Section II, we assume that the amount of maintenance required by a used durable unit in the second period is only observed by the individual who consumed that unit in the first period, where in this case that means that at the beginning of the second period the consumer privately observes the number of replacement parts that will be required by his or her used durable unit.[15] Further, replacement parts for a durable unit produced by firm j can only be manufactured by firm j itself, where the firm either allows competition in the maintenance market by selling replacement parts to alternative maintenance suppliers or monopolizes the maintenance market by refusing to sell replacement parts.

Analysis of this model yields that, if each durable goods producer cannot commit in the first period to a price for new units in the second period, then as in Section II each firm monopolizes the maintenance market for its own product. There is a difference, however, in that now each firm chooses this behavior rather than allow competition in the maintenance market and simply increase the price of replacement parts.[16] The logic for this result is as follows. Similar to what we found in Proposition 2, in this analysis each durable goods producer extracts all the surplus from consumers who maintain their used units in the second period by charging

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[15] Although we have not formally shown this, we believe the conclusions also follow if each consumer does not observe the exact number of replacement parts that will be required by his or her used unit, but only observes a signal indicating the expected number of parts that will be required.

[16] If we combined the two extensions then, whether or not a firm could commit in the first period to a price for new units in the second period, each durable goods producer would monopolize the maintenance market for its own product rather than allow competition in that market and simply increase the price of replacement parts.

these consumers a price for maintenance equal to $c+\Delta-z$. That is, extracting all the surplus from these consumers requires that the price charged to each such consumer for maintenance be independent of the amount of maintenance required by the consumer's used unit, or, more precisely, be independent of the number of replacement parts required.

Given this, suppose a firm does not monopolize the maintenance market but rather simply increases the price of replacement parts. Let c_S be the cost of providing one unit of service, P_R be the price the durable goods producer charges for a replacement part, and r_i denote the number of replacement parts required by the used unit consumed by individual i in the first period. Because the maintenance market is competitive, in equilibrium the price charged for maintenance that consists of one unit of service and r_i replacement parts will be $c_S+r_iP_R$. That is, the price of maintenance will be increasing in the number of replacement parts required. But since extracting all the surplus from consumers who choose to maintain their used units requires that these consumers pay a price for maintenance that is independent of the number of replacement parts required, we now have that by simply increasing the price of replacement parts the firm is unable to extract all the surplus in the second period from the consumers who choose to maintain their used units. Hence, since monopolizing the market for maintenance allows a firm to extract all the surplus from these consumers while simply increasing the price of replacement parts does not, the firm will choose to monopolize the maintenance market.

IV. DISCUSSION

In Sections II and III we provided an explanation for why a durable goods producer with little or no market power in the market for new units would refuse to sell spare parts to alternative maintenance suppliers and in this way monopolize the maintenance market for its own product. This section contains two discussions. First, we discuss the major alternative explanations that have been put forth for why a durable goods producer would monopolize the maintenance market for its own product. Second, we discuss the antitrust implications of our analysis.

A) <u>Alternative Theories</u>

A number of alternative explanations have been put forth concerning why a durable goods producer would monopolize the maintenance market for its own product, where, in contrast to the analysis of Sections II and III, in most of these explanations the practice reduces rather than increases social welfare. After a brief preliminary discussion, we discuss three closely related theories in which the firm monopolizes the maintenance market in order to exploit market power after consumers are locked-in. We then discuss the price discrimination explanation for the phenomenon and Shapiro's reputation argument. More in depth discussions of alternative theories appear in Shapiro (1995) and Chen, Ross, and Stanbury (1998).

The literature does not always make a clear distinction between the terms consumer lock-in and consumer switching costs. In the discussion that follows we do make a clear distinction between these terms. We use the term consumer lock-in to refer to a setting in which a consumer who has purchased a durable good needs to also purchase maintenance to consume the good. We use the term consumer switching costs to refer to a setting in which a consumer faces a cost of switching between producers at the date that the consumer replaces a used unit with a new unit. The three theories discussed below require consumer lock-in but not consumer switching costs, i.e., a durable unit requires maintenance but a consumer is indifferent between different firms' products at the time that replacement occurs. In contrast, our analysis incorporates both consumer lock-in and consumer switching costs, i.e., a durable unit requires maintenance and at the replacement date a consumer prefers a new unit produced by the same firm that manufactured the unit the individual consumed in the previous period.

One theory that has been put forth is referred to as the "surprise" theory. The two key elements here are that consumers are locked-in once they purchase a new unit of output from a durable goods producer, and consumers expect that the maintenance market will be competitive. What happens is that the producer exploits the consumers' locked-in positions by first stopping other firms from selling maintenance and then raising the price of maintenance. In this theory

consumers are hurt by the maintenance market monopoly both because the surprise causes the equivalent of a lump sum transfer between the consumers and the firm, and because monopoly pricing of maintenance results in a standard deadweight loss. The deadweight loss in this case has two components. Consumers of used units purchase less than the socially optimal amount of maintenance and consumers replace their used units too quickly.

A closely related explanation is referred to as the "costly information" theory. This theory is similar to the surprise theory discussed above in that the durable goods producer exploits the locked-in positions of consumers by monopolizing the maintenance market and raising the price of maintenance. The difference is that this is not a surprise to consumers but rather consumers simply ignore the cost of maintenance in their original decisions to purchase new units. In contrast to the surprise theory, there is no transfer between the consumers and the firm because competitive firms will reduce the price for new units so that they receive zero profits in equilibrium.[17] However, similar to the surprise theory, the monopoly pricing of maintenance results in a deadweight loss.[18]

The third theory that depends on the exploitation of locked-in consumers is the "lack of commitment" theory developed in Borenstein et al. (1995). In contrast to the two theories described above, in this explanation consumers correctly anticipate whether a durable goods producer will monopolize the maintenance market and are willing to pay less for a new unit when they anticipate monopolization. In such circumstances a durable goods producer would want to commit to allowing competition in the maintenance market, but monopolization occurs because of a lack of ability to commit. In this theory, as in the costly information theory, the only cost of the practice is the deadweight loss due to the monopoly pricing of maintenance.[19]

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[17] The discussions we have seen of the surprise theory do not make clear why in that theory competition in the market for new units does not eliminate the transfer between consumers and firms (note: there was a related discussion at the end of Section II).

[18] One other difference between the theories is that in the surprise theory a durable goods producer that monopolizes the maintenance market is hurt in the market for new units because it establishes a reputation for exploiting locked-in consumers. This is not true in the costly information theory.

One can question the applicability of each of the above theories to the recent cases in which monopolizing the maintenance market has been observed. For example, the costly information theory assumes uninformed consumers which seems unlikely in some of the recent cases in which the cost of maintenance was a significant proportion of the total cost of using the product. Similarly, the lack of commitment theory assumes commitment is not possible but this also seems to be of questionable applicability because long-term maintenance contracts are quite common in many of the industries in which the practice has been observed. Further, there is another criticism that applies equally to all three theories. As discussed earlier, in the typical case the durable goods producer monopolizes the maintenance market by refusing to sell spare parts to alternative maintenance suppliers. The problem is that, in the original formulations, none of the three theories explains this behavior. In each of the theories the durable goods producer could have achieved its goal by simply raising the price of spare parts rather than monopolizing the maintenance market by refusing to sell spare parts to alternative maintenance suppliers.[20]

Another explanation for maintenance market monopoly is that the practice helps a firm more effectively price discriminate (this explanation is developed in Klein (1993) and Chen and Ross (1993)). This is the standard metered sales explanation for tie-ins that was used, for example, to explain IBM's practice of requiring purchasers of its tabulating machines to also purchase cards from IBM. That is, in this theory consumers with higher valuations for the

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[19] Both Shapiro (1995) and Chen and Ross (1998) provide formal analyses that suggest this deadweight loss is likely to be small.

[20] One way of extending each of these theories so that monopolizing the maintenance market is preferred to simply raising the price of spare parts is by assuming that service and the replacement of defective parts are substitutes in the maintenance production function. Given this assumption, if the durable goods producer simply raised the price of spare parts, the alternative maintenance suppliers would respond by inefficiently substituting service for spare parts. Hence, monopolizing the maintenance market would be more profitable because it would avoid this inefficient substitution of service for spare parts. It is interesting to note that, in contrast to the public policy recommendation that follows from the simple version of each of the theories, this extension suggests that the government should allow durable goods producers to monopolize the maintenance markets for their own products unless the government also regulates the price of spare parts. The reason is that, if the government does not regulate the price of spare parts, there will be a monopoly price for maintenance whether or not the government allows monopolization of the maintenance market and thus allowing monopolization is superior from a social welfare standpoint because it avoids the inefficient substitution of service for spare parts.

durable goods producer's product are also heavier users of maintenance, with the result that the seller can more effectively price discriminate by monopolizing the maintenance market and raising its price. This theory provides a rationale for why a firm with market power would monopolize the maintenance market for its own product, but does not explain why a firm with little or no market power would monopolize the maintenance market for its own product.[21]

The last argument we will discuss is the reputation argument put forth in Shapiro (1995). Shapiro considers a setting in which a durable goods producer is in the market for multiple periods and a firm's behavior in the market in one period affects consumer expectations in future periods. Shapiro argues that if a firm's incentive to maintain a positive reputation is sufficiently strong, then a durable goods producer that monopolizes the maintenance market for its own product will charge a competitive price rather than a monopoly price for maintenance. The logic is that, even though short-run profits are higher if the firm increases the maintenance price above the competitive price, due to the effect on long-run profits the firm chooses not to take advantage of its monopoly position and charges a competitive price. Note that Shapiro's argument does not in fact provide an explanation for why a durable goods producer would monopolize the maintenance market in the first place. That is, since a durable goods producer that monopolizes the maintenance market for its own product charges the competitive price for maintenance, the firm's profitability is no higher than if it did not enter the maintenance market and instead allowed maintenance to be provided by the competitive sellers.

In summary, there are a number of alternative explanations for why a durable goods producer would monopolize the maintenance market for its own product. However, we believe that the explanation put forth in Sections II and III is a better match than any of the alternatives for the evidence in the Kodak case and other cases in which a firm with little or no market power monopolized the maintenance market for its own products. For example, our theory explains

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[21] Klein argues that in the real world there is significant price discrimination even by firms with little market power, and thus that the price discrimination argument should not be ruled out as a possible explanation for why such a firm would monopolize the maintenance market for its own products.

why a durable goods producer would monopolize the maintenance market even if consumers are well informed and long-term contracts are feasible. In contrast, the costly information and lack of commitment theories do not explain why a firm would monopolize the maintenance market in such a case. Our theory is also consistent with a firm monopolizing the maintenance market when it has little or no market power, while the price discrimination theory fits more easily with firms characterized by significant market power.[22] Finally, as discussed further in the next subsection, our theory is the only one that incorporates consumer switching costs in an essential way and the evidence indicates that this was an important aspect of a number of the cases (see footnote 2 for evidence concerning Kodak and the importance of switching costs).

B) <u>Antitrust Implications</u>

Since the Kodak decision, significant attention has been paid to whether a durable goods producer with little or no market power in the market for new units should be allowed to monopolize the maintenance market for its own products by refusing to sell spare parts to alternative maintenance suppliers. Based on previous theoretical explanations for this behavior discussed in Subsection IV.A, a number of authors have argued that prohibiting such behavior serves to enhance social welfare in certain settings (see, e.g., Salop (1999)). We now discuss the implications of our analysis for whether the Courts should allow a durable goods producer with little or no market power to monopolize the maintenance market for its own products.

We begin by reviewing what happens in our model when monopolizing the maintenance market is and is not allowed. Suppose that firms cannot commit in the first period to a second-period price for new units and the maintenance market is competitive. We showed that in this case, due to switching costs, firms charge a high price for new units in the second period which,

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[22] Recently, both Hendel and Lizzeri (1999) and Spiegel and Yehezkel (2000) put forth additional explanations for why a durable goods producer with market power would monopolize the maintenance market for its own product. In Hendel and Lizzeri's argument a monopolist in the market for new units monopolizes the maintenance market in order to control the speed with which the quality of its product deteriorates, where this is optimal because of the substitutability between new and used units of output. In Spiegel and Yehezkel's argument the firm monopolizes the maintenance market in order to stop low-quality maintenance from being offered, where this is optimal because it allows the firm to increase the price it charges for high-quality maintenance.

in turn, reduces both social welfare and consumer welfare. This reduction occurs because consumers respond to the high second-period price for new units by sometimes maintaining used units when it would be efficient to replace those units. Now suppose that each firm has the option of monopolizing the maintenance market for its own product. The result is that each firm monopolizes the maintenance market and, because this avoids the inefficiency concerning consumer maintenance decisions, there is a corresponding increase in both social welfare and consumer welfare.

The question is, what do these results imply for the question considered by the Supreme Court in the *Kodak* decision, i.e., should a durable goods producer with little or no market power in the market for new units be allowed to monopolize the maintenance markets for its own products? The Court's ruling was that, even if Kodak had no market power in the market for new units, it could still be guilty of having illegally monopolized the maintenance markets for its own products by refusing to sell spare parts to alternative maintenance suppliers. This ruling is consistent with the arguments of Borenstein et al. and others discussed in the previous subsection. They argue that when Kodak monopolized the maintenance market social welfare fell because a monopoly price for maintenance results in a standard deadweight loss, where this loss consists of two components. One component is that consumers purchase less than the socially optimal amount of maintenance, while the other is that consumers replace their used units too quickly.

An important contribution of our analysis is to show that in the presence of consumer switching costs the social welfare implications of how monopolizing the maintenance market affects replacement decisions are quite different than in the analyses of Borenstein et al. and others. In particular, our analysis shows that, if in a setting characterized by competitive durable goods producers there are consumer switching costs in addition to lock-in, then a competitive price for maintenance can result in consumers replacing used units inefficiently often while monopoly maintenance results in efficient decisions on this dimension. Recall that the presence of consumer switching costs was an important aspect of the Kodak case (see footnote 2 for a

brief discussion). Hence, we would argue that Kodak should have been allowed to monopolize the maintenance market because in the type of setting found in the *Kodak* case the result of monopolization is improved efficiency concerning the replacement versus maintenance decision.

On the other hand, in the absence of consumer switching costs the argument for not allowing maintenance market monopolization is stronger. In the absence of switching costs, the arguments of Borenstein et al. and others suggest that maintenance market monopolization may reduce social welfare because consumers purchase too little maintenance and replace their machines too often. Hence, in such a setting not allowing maintenance market monopolization may very well increase both social welfare and consumer welfare. There is one complication to this argument, however. Suppose there are no consumer switching costs and a durable goods producer wants to monopolize the maintenance markets for its own products for reasons consistent with the arguments of Borenstein et al. and others. Further, suppose the firm achieves monopolization by refusing to sell spare parts to alternative maintenance suppliers. Then eliminating the inefficiency might require not only for the firm to sell spare parts to the alternative suppliers but also for the government to regulate the price for spare parts (otherwise, the firm could achieve most or all of what it wants by simply raising the price for spare parts). But this is problematic because it is not at all clear that regulating the price of spare parts is a feasible intervention for the antitrust authorities.

V. CONCLUSION

In this paper we demonstrated two important results. Consider a setting characterized by consumers switching costs and an inability on the part of durable goods producers to commit to the future price for replacement units. Our first finding is that, if both the market for new durable units and the maintenance market are competitive, then an inefficiency results that lowers both social welfare and consumer welfare. The logic is that, in order to achieve efficient maintenance decisions on the part of consumers, a firm would like to commit to a price for replacement units equal to the marginal cost of production. However, in the absence of the

ability to commit, the presence of consumer switching costs causes firms to charge a price for replacement units that is above marginal cost. The result is inefficient maintenance decisions and a corresponding reduction in both social welfare and consumer welfare.

Our second important finding is that monopolizing the maintenance market for its own product is a way for a competitive durable goods producer to avoid the inefficiency described above. By monopolizing the maintenance market a firm is able to extract all the surplus at the date consumers are choosing whether to maintain or replace their used units. The result is that, because it is capturing all the surplus, the firm has an incentive to price in such a way that consumers make efficient choices concerning whether to maintain or replace used units. In other words, by monopolizing the maintenance market for its own product a competitive durable goods producer causes both social welfare and consumer welfare to increase.

There are a number of directions in which the analysis in this paper could be extended. However, the one that we feel is the most interesting is extending our result concerning the importance of commitment in competitive durable goods markets. Building on the initial insight of Coase (1972), earlier literature on commitment in durable goods markets focuses on monopoly models.[23] In Section II we showed that whether or not a firm has the ability to commit can also be important in a competitive durable goods setting when there are consumer switching costs. This finding is interesting because it suggests that the issue of commitment may be important in many more durable goods markets than previously realized. In future work we plan to extend our analysis both by investigating whether there are alternative avenues through which the ability to commit becomes important in competitive settings, and whether there are practices other than monopolizing the maintenance market that competitive firms may employ in order to avoid problems due to an inability to commit.

APPENDIX

Due to space considerations, proofs are somewhat abbreviated.

PROOF OF PROPOSITION 1: Consider firm j's second-period pricing decision where firm j sold a strictly positive number of new units in the first period. If $P_{j2}^C \leq c$, then the firm's second-period profits are less than or equal to zero. Similarly, if $P_{j2}^C > c + \Delta$, then the firm's second-period profits equal zero. This follows given our assumption that there is free entry into the market for new durable units in both the first and second periods (see footnote 8) since this means other firms will be willing to sell new units in the second period at a price c. If $c < P_{j2}^C \leq c + \Delta$, then a consumer who purchases a new unit from firm j in the first period will purchase a new unit from firm j in the second period if the consumer decides to purchase a new unit (to be precise, if $P_{j2}^C = c + \Delta$ then the consumer is indifferent between purchasing a new unit from firm j in the second period and purchasing a new unit from a firm that sells new units in the second period at a price c). We know this because no durable goods producer would offer a new unit in the second period at a price less than c.

Given the above, since $M > c - z$, we have that there are values for P_{j2}^C that satisfy $c < P_{j2}^C \leq c + \Delta$ such that second-period profits for firm j are strictly positive. In turn, this implies that for every firm j that sold a strictly positive number of new units in the first period the unique optimal value for P_{j2}^C satisfies $c = P_{j2}^* < P_{j2}^C \leq c + \Delta$ (see footnote 3).[24] Further, given that competition must cause each firm to earn zero expected profits in equilibrium, we also now have that every firm j that sells a strictly positive number of new units in the first period must have the same value for P_{j1}^C where this value satisfies $P_{j1}^C < P_{j1}^* = c$. Let P_1^C denote the shared value for P_{j1}^C while P' denotes the shared value for P_{j2}^C. This proves i).

Now consider the second-period behavior of consumer i who purchased a new unit in the first period. In the second period this consumer has four choices. First, the consumer could

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[23] Other papers in this literature include Bulow (1982,1986), Ausubel and Deneckere (1989), Waldman (1993), and Karp and Perloff (1996).

[24] In a proof available from the authors upon request we show that there is a unique optimal value for P_{j2}^C if m is uniformly distributed over the interval (0,M].

maintain the unit and receive a second-period net benefit equal to $v_i+\Delta-m_i$. Second, the consumer could replace the unit with a new unit produced by firm j_i. This yields consumer i a second-period net benefit equal to $v_i+\Delta+z-P'$. Third, the consumer could replace the unit with a new unit produced by another firm. This yields consumer i a second-period net benefit equal to v_i+z-c since there will be other firms willing to sell a new unit to consumer i at a price c. Fourth, the consumer could decide not to use the unit and not replace it. This yields consumer i a second-period net benefit equal to z. Since $v_L>c$, we know the consumer will never choose the fourth option. Further, since $c<P'\leq c+\Delta$ we know the following. The consumer maintains the used unit when $m_i\leq P'-z$, replaces the used unit with a new unit produced by firm j_i when $m_i>P'-z$ and $P'<c+\Delta$, and replaces the used unit with a new unit produced by firm j_i or a new unit produced by a different firm when $m_i>P'-z$ and $P'=c+\Delta$ (see footnote 9).

Suppose that there exists a firm j that sells a strictly positive number of new units in the first period, chooses $P_{j2}^C=c+\Delta$, and has a strictly positive expected number of its first-period consumers replace their used units in the second period and purchase new units from other firms. Then the firm could increase its second-period profits by infinitesimally lowering P_{j2}^C below $c+\Delta$ since the result would be that all of its first-period consumers who replace their used units in the second period would then purchase new units from firm j. This means that in equilibrium all of firm j's first-period consumers who replace their used units in the second period must purchase new units from firm j. That is, in the second period each consumer i maintains his or her used unit when $m_i\leq P'-z$ and replaces the used unit with a new unit produced by firm j_i when $m_i>P'-z$. We also know that every consumer i purchases a new unit in the first period given $v_L>c$. This proves ii).

Now consider EU_i^C. Given the above, EU_i^C is given by (A1).

(A1)
$$EU_i^C=v_i-P_1^C+\beta[v_i+\Delta-\int_0^{P'-z} mf(m)dm-\int_{P'-z}^M (P'-z)f(m)dm]$$

Given competition means that in equilibrium all durable goods producers earn zero expected profits, we know $P_1^C-c+\beta\int_{P'-z}^M (P'-c)f(m)dm=0$. Substituting this into (A1) yields (A2).

(A2)
$$EU_i^C=v_i-c+\beta[v_i+\Delta-\int_0^{P'-z} mf(m)dm-\int_{P'-z}^M (c-z)f(m)dm]$$

Given P′>c, a comparison of (A2) and the expression for EU$_i$* in the text yields EU$_i^C$<EU$_i$* for all i. This proves iii).

PROOF OF PROPOSITION 2: Consider firm j which sells a strictly positive number of new units in the first period. At the beginning of the second period the firm must decide whether or not to monopolize the maintenance market for its own product. If the firm does not monopolize the maintenance market, then its second-period behavior is given in the proof of Proposition 1. Based on that analysis, in that case the second-period profits of the firm, denoted π_{j2}, is given by

$\pi_{j2}=n_j \int_{P'-z}^{M}$ (P′-c)f(m)dm, where c<P′≤c+Δ and n$_j$ is the number of new units sold by firm j in period 1.

Now suppose the firm decides to monopolize the maintenance market. From the standpoint of second-period profits, the best the firm can do in the second period is capture all of the surplus from consumers who purchased a new unit from the firm in the first period. By that we mean the following. Let consumer i now be a consumer who purchased a new unit from firm j in the first period. First, if consumer i purchases another new unit from the firm in the second period then consumer i should be indifferent between this behavior and purchasing a new unit in the second period from another firm at a price c, i.e., consumer i should pay c+Δ to firm j for a new unit. Second, if consumer i maintains his or her used unit in the second period the consumer should similarly be indifferent between this behavior and purchasing a new unit in the second period from another firm at a price c, i.e., consumer i should pay c+Δ-z for maintaining his or her used unit. Third, given the firm receives c+Δ for a new unit and c+Δ-z for maintenance, the firm maximizes its second-period profits by selling a new unit to consumer i when m$_i$>c-z, selling the consumer maintenance when m$_i$<c-z, and either selling a new unit to consumer i or selling the consumer maintenance when m$_i$=c-z. Let π_{j2}^{M}* denote the firm's second-period profit level when every consumer i behaves in this way.

Given the above, every equilibrium to the subgame that starts after firm j decides to monopolize the maintenance market is characterized by P$_{j2}^{M}$=c+Δ, p$_j$(m)=c+Δ-z for all m<c-z, p$_j$(m)>c+Δ-z for all m>c-z, and p$_j$(m)≥c+Δ-z for m=c-z.[25] There are two steps to the argument.

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[25] To be precise, we show there is no equilibrium that is characterized by prices that do not satisfy these conditions for a strictly positive measure of realizations for m.

Let consumer i again be a consumer who purchased a new unit from firm j in the first period. First, faced with prices that satisfy these conditions an optimal strategy for consumer i is to behave as described above. That is, an optimal strategy for consumer i is to maintain his or her used unit when $m_i<c-z$, replace the unit with a new unit purchased from firm j when $m_i>c-z$, and either maintain the unit or replace the unit with a new unit purchased from firm j when $m_i=c-z$ (in this last case the consumer maintains the unit if $p_j(c)=c+\Delta-z$ and replaces the unit if $p_j(c)>c+\Delta-z$). Since the above described behavior for consumer i is the optimal behavior from firm j's perspective, an equilibrium to the subgame that starts after firm j decides to monopolize the maintenance market is that firm j chooses a pricing strategy that satisfies $P_{j2}^M=c+\Delta$, $p_j(m)=c+\Delta-z$ for all $m<c-z$, $p_j(m)>c+\Delta-z$ for all $m>c-z$, and $p_j(m)\geq c+\Delta-z$ for $m=c-z$, and each consumer i who purchased a new unit from firm j in the first period chooses the behavior described above.

The second step is to show that there is no other equilibrium to the subgame that starts after firm j decides to monopolize the maintenance market. Since having the consumer purchase maintenance at a price $c+\Delta-z$ when $m_i<c-z$, replace the unit with a new unit purchased from firm j at a price $c+\Delta-z$ when $m_i>c-z$, and exhibit either behavior when $m_i=c-z$ is the optimal behavior for consumer i from firm j's perspective, any pricing strategy that does not satisfy $P_{j2}^M=c+\Delta$, $p_j(m)=c+\Delta-z$ for all $m<c-z$, $p_j(m)>c+\Delta-z$ for all $m>c-z$, and $p_j(m)\geq c+\Delta-z$ for $m=c-z$ must yield lower profits for the firm (see footnote 25). But the firm could set $P_{j2}^M=c+\Delta-\varepsilon$, $p_j(m)=c+\Delta-z-\varepsilon$ for all $m<c-z$, and $p_j(m)>c+\Delta-z$ for all $m\geq c-z$, and for every $\varepsilon>0$ the unique best response for consumer i would be to maintain his or her used unit when $m_i<c-z$ and purchase a new unit from firm j when $m_i\geq c-z$. In turn, this means that by choosing ε sufficiently small the firm can guarantee that its second-period profit level exceeds any level that is strictly less than π_{j2}^M*. Hence, any pricing strategy that does not satisfy $P_{j2}^M=c+\Delta$, $p_j(m)=c+\Delta-z$ for all $m<c-z$, $p_j(m)>c+\Delta-z$ for all $m>c-z$, and $p_j(m)\geq c+\Delta-z$ for $m=c-z$ cannot be part of an equilibrium because for any such strategy there is always an alternative strategy that increases the firm's second-period profits.

Given the above, we can now consider whether firm j has an incentive to monopolize the maintenance market at the beginning of the second period. As stated earlier, if the firm does not

monopolize the maintenance market, then its second-period profits are given by $\pi_{j2}=n_j \int_{P'-z}^{M}$ $(P'-c)f(m)dm$, where $c<P'\leq c+\Delta$. If the firm does monopolize the maintenance market, then based on the above analysis it second-period profits are given by $\pi_{j2}=n_j [\int_{0}^{c-z}$ $(c-z+\Delta-m)f(m)dm$

$+\int_{c-z}^{M}$ $\Delta f(m)dm]$. Given $c<P'\leq c+\Delta$, a comparison of the two expressions yields that firm j will choose to monopolize the maintenance market at the beginning of the second period.

Now consider EU_i^{M}. Given the above, EU_i^{M} is given by (A3).

(A3) $$EU_i^{M}=v_i-P_{j1}^{M}+\beta(v_i+z-c)$$

Given competition means that in equilibrium all durable goods producers earn zero expected profits, we know $P_{j1}^{M}-c+\beta[\int_{0}^{c-z}$ $(c-z+\Delta-m)f(m)dm+\int_{c-z}^{M}$ $\Delta f(m)dm]=0$ or $P_{j1}^{M}=c+\beta[\int_{0}^{c-z}$ $(m-c+z-\Delta)f(m)dm-\int_{c-z}^{M}$ $\Delta f(m)dm]$. Substituting this into (A3) yields (A4).

(A4) $$EU_i^{M}=v_i-c+\beta[v_i+\Delta-\int_{0}^{c-z}$ $mf(m)dm-\int_{c-z}^{M}$ $(c-z)f(m)dm]$$

A comparison of (A4) and the expression for EU_i^{*} in the text yields $EU_i^{M}=EU_i^{*}$ for all i. Further, given $v_L>c$, all consumers purchase a new unit of output in the first period. This completes the proof.

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